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Space Time Block Code Achieving Full Diversity for MIMO System with Linear Receiver

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Abstract:A general criterion for space-time block codes (STBC) to achieve full diversity with a linear receiver is used for a wireless communication system having multiple transmitter and multi receiver antennas [multiple-input–multi-output (MIMO)]. Space-Time Block codes (STBC) provide a means for combating the effects of multipath fading without adding much complexity to the receiver. Here zero-forcing receiver is proposed to extract full diversity.In this we investigate the impactof error performance analysis of STBC.

Key Words:Space-time block codes (STBCs)**,**multi-input multi-output(MIMO), Full diversity**,** linear receiver.

I. INTRODUCTION

The performance of the wireless communication systems can beenhanced by using multiple transmit and receive antennas, which is generally referredto as the MIMO technique, and has been incorporated into the IEEE 802.11n standard,i.e. one of the Wi-Fi systems.[1]The space time coding is a promising way to realize the gain in thewireless communications system using MIMO.MIMO uses multiple antennas to send multiple parallel signals from transmitter. In an urban environment, these signals will bounce off trees, buildings, etc. and continue on their way to their destination but in different directions. "Multi-path" occurs when the different signals arrive at the receiver at various times. With MIMO, the receiving end uses an algorithm or special signal processing to sort out the multiple signals to produce one signal that has the originally transmitted data.[5]

Severe attenuation in a multipath wireless environmentmakes it extremely difficult for the receiver to determinethe transmitted signal unless the receiver is provided withsome form of diversity, i.e., some less-attenuated replica ofthe transmitted signal is provided to the receiver[2].Transmitting the replica of the signal is called diversity.A widely applied technique to reduce theeffects of multipath fading is antenna diversity. Usually, multiple antennas are used at the receiver with some kind of combining of the received signals. However, transmit and receive diversity techniques can be applied in the uplink and/or the downlink.

STBC is a technique used in wireless communication to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer. The fact that the transmitted signal must traverse a potentially difficult environment with scattering, reflection, refraction and so on and may then be further corrupted by thermal noise in the receiver means that some of the received copies of the data will be 'better' than others. This redundancy results in a higher chance of being able to use one or more of the received copies to correctly decode the received signal [3],[4]. In fact, space–time coding combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible.

II. RELATED WORK

Existing method of this paper is, focus the error performance analysis of space time block code for square QAM modulation. Here non coherent zero forcing receiver is proposed and able extract full diversity from STBC. Christo Ananth et al. [7] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a

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fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation where the assumption of existence of "ground-truth" reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

Let us consider a MISO system with M transmitter antennas and asingle receiver antenna, in which the fading coefficients of the channelare constant for T symbol intervals and independently change fromone block realization to another.[8] For such a system, a training spacetime-block-coded baseband channel model can be represented as

$$\mathrm{y} = \mathrm{Xh} + \mathrm{w} \tag{1}$$

Here, $\mathbf{y}$ is a $T\times1$ received signal vector, $\mathbf{X}$is a transmitting signal matrix, $\mathbf{h}$ is an$M\times 1$ channel vector, and $\mathbf{w}$ is a $T\times 1$noise vector.The training transmission consists of two phases [22]–[26]. The firstphase is training, i.e., the transmitter sends the known training signals

$$y_\tau = \sqrt{\rho_d} X_d h + w_d (2)$$

where $\boldsymbol{y_\tau}$is a $\boldsymbol{T_\tau}\times 1$ received signal vector during the first$\boldsymbol{T_\tau}$time slots; $\boldsymbol{\rho_\tau}$, $0<\boldsymbol{\rho_\tau}<1$, is the energy factor for the training symbols; $\boldsymbol{X_\tau}$is a $\boldsymbol{T_\tau}\times M$ matrix of training symbols known at the receiver; and $\boldsymbol{w_\tau}$is a $\boldsymbol{T_\tau}\times 1$ noise vector[9]. The second phase spends $Td = T - M$ time slots on data transmission such that the corresponding received signals are given by

$$y_d = \sqrt{\rho_d} X_d h + w_d \tag{3}$$

where $y_d$is a $Td \times 1$ received signal, $\rho_d = 1-\rho_\tau$is the energy factor for the data symbols, $X_d$is the $Td \times M$ data matrixand $\mathbf{w}d$is a $Td \times 1$ noise vector. Now, stacking(2) and (3) yields[6]-[11].

$$\begin{pmatrix} y_\tau \\ y_d \end{pmatrix} = \begin{pmatrix} \sqrt{\frac{\rho_\tau}{M}} I_M \\ \sqrt{1-\rho_\tau X_d} \end{pmatrix} h + \begin{pmatrix} w_\tau \\ w_d \end{pmatrix} \tag{4}$$

One ofthe advantages of the linear dispersion-coded channel model is thatthere exists an equivalent channel model such that

$$r = \sqrt{\rho_d} H(h) s + \epsilon \tag{5}$$

where$\mathbf{r}$ is a $Td \times 1$ equivalent received signal vector, ξ is a $Td \times 1$equivalent noise vector and $H(\mathbf{h})$is called an equivalent channel matrix including the normalization coefficient. In particular, this paper, we are interested in the underlyingcoherent linear dispersion code enabling full diversity for linear receivers. The following are typical coherentSTBCs that are able to provide full diversity for the linear receivers.

Overlapped Alamouti STBC [5]: The coding matrixis given by

$$X_d(s) = \sqrt{\alpha} \begin{pmatrix} s_1 & 0 & \ddots & 0 & 0 \\ 0 & s_1^* & \ddots & 0 & 0 \\ s_3 & 0 & \ddots & 0 & 0 \\ \ddots & s_3 & \ddots & \vdots & \vdots \\ s_{k-1} & \vdots & \ddots & s_1 & 0 \\ \vdots & s_{k-1}^* & \ddots & 0 & s_1^* \\ \vdots & \vdots & \ddots & s_3 & 0 \\ \vdots & \vdots & \ddots & \ddots & s_3^* \\ \vdots & \vdots & \ddots & s_{k-1} & \vdots \\ 0 & 0 & \ddots & 0 & s_{k-1}^* \end{pmatrix}_{T_d * M}$$

$$+\sqrt{\alpha} \begin{pmatrix} 0 & 0 & \ddots & 0 & s_2 \\ 0 & 0 & \ddots & -s_2^* & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & s_2 & \ddots & \vdots & s_K \\ -s_2^* & 0 & \ddots & -s_L^* & 0 \\ 0 & s_4 & \ddots & 0 & 0 \\ -s_4^* & 0 & \ddots & 0 & 0 \\ \vdots & \vdots & \ddots & \ddots & 0 \\ 0 & s_K & \ddots & 0 & \vdots \\ -s_K^* & 0 & \ddots & 0 & 0 \end{pmatrix}_{T_d * M}$$

The transmission symbol rate is $K/(K+M-2)$ when K and$M$ are even.

Alamouti-Toeplitz STBC [6]: The coding matrix is given by

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$$[X_d(s)]_{(2m-1):2m,(2n-1):2n} = \begin{cases} \sqrt{\alpha} S_{m-n+1}, & if\ 0 \le m-n < \frac{k}{2} \\ 0 & other\ wise \end{cases}$$

where K, M, and T are even numbers, and each S_k for k=1,2,…..$\frac{K}{2}$ is the Alamouti coding matrix, i.e., $S_k = \begin{pmatrix} s_{2k-1} & s_{2k} \\ -s_{2k}^* & s_{2k-1}^* \end{pmatrix}$. The transmission symbol rate is $\frac{K}{(K+M-2)}$.

III. SYSTEM MODEL

A general system model of MIMO system is shown here

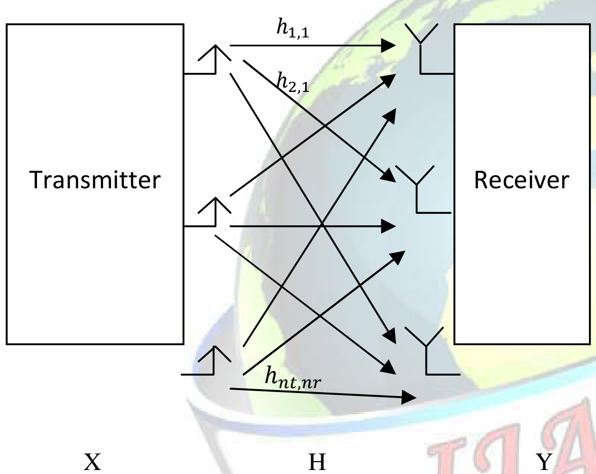

Figure 1. MIMO model with nt transmitantennas and nr receive antennas.

Here the transmitter is denoted as X and receiver is denoted as Y and fading channel is denoted as H. each one of the transmitter send the signal to the all the receiver so at the receiving side using some algorithm to combine the signal and give best output. Let h i,j be a complex number correspondingto the channel gain between transmit antenna i andreceive antenna j respectively. If at a certain timeinstant the complex signals {s1, s2, ……. s n t} aretransmitted via n t transmit antennas, then nr thereceived antenna j can be expressed as:

$$y_i = \sum_{j=1}^{n_t} h_{i,j} S_j + n_i \tag{6}$$

Where n_i is a noise term. Combining allreceive signals in a vector y, then (6) can be easilyexpressed in matrix form

$$y = H_s + n \tag{7}$$

Where y is the $n_r * 1$ receive symbol vector, H is the $n_r * n_t$ MIMO channel transfer matrix givenby

$$H = \begin{bmatrix} h_{11} & h_{12} & \dots & h_{1,nt} \\ h_{21} & h_{22} & \dots & h_{2,nt} \\ \vdots & \vdots & \dots & \vdots \\ h_{nr,1} & h_{n2} & \dots & h_{nr,nt} \end{bmatrix}$$

s is the$n_t * 1$ transmit symbol vector andn is the $n_r * 1$ additive noise vector. Note that thesystem model implicitly assumes a flat fading MIMOchannel, i.e., channel coefficients are constant duringthe transmission of several symbols.

Overlapped Alamouti STBC:[3]
Encoding algorithm

A space-time block code is defined by a *p* x *n* transmission matrix *H*. The entries of the matrix *H* are linear combinations of the variable x_1, x_2, …,x_k and their conjugates. The number of Transmission antennas is n.

Examples: H_2 represents a code that utilizes two antennas, H_3 represents a code that utilizes three antennas andH_4 represents a code that utilizes four antennas.

$$H_2 = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}$$

$$H_3 = \begin{bmatrix} x_1 & x_2 & x_3 \\ -x_2 & x_1 & -x_4 \\ -x_3 & x_4 & x_1 \\ -x_4 & -x_3 & x_2 \\ x_1^* & x_2^* & x_3^* \\ -x_2^* & x_1^* & -x_4^* \\ -x_3^* & x_4^* & x_1^* \\ -x_4^* & -x_3^* & x_2^* \end{bmatrix}$$

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$$H_4 = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2 & x_1 & -x_4 & x_3 \\ -x_3 & x_4 & x_1 & -x_2 \\ -x_4 & -x_3 & x_2 & x_1 \\ x_1^* & x_2^* & x_3^* & x_4^* \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ -x_3^* & x_4^* & x_1^* & -x_2^* \\ -x_4^* & x_3^* & x_2^* & x_1^* \end{bmatrix}$$

Alamouti-Toeplitz STBC [4]: The coding matrix is

$$[X_d(s)]_{(2m-1):2m,(2n-1):2n} = \begin{cases} \sqrt{\alpha} S_{m-n+1}, & if\ 0 \le m-n < \frac{k}{2} \\ 0 & other\ wise \end{cases}$$

where K, M, and T are even numbers, and each S_k for k=1,2,…..$\frac{K}{2}$ is the Alamouti coding matrix, i.e., $S_k = \begin{pmatrix} s_{2k-1} & s_{2k} \\ -s_{2k}^* & s_{2k-1}^* \end{pmatrix}$. The transmission symbol rate is $\frac{K}{(K+M-2)}$.

IV. FULL DIVERSITY SPACE-TIME BLOCK CODES WITH LINEAR RECEIVER

Here the training ZF and ZF-DFE receivers used for the space-time block coded channel model (1) and then full diversity is achieved from the space time block code with the zero forcing receiver.

ZF Receiver:

First we analyze the zero forcing receiver these consists of two process. Here first estimate the fading channel using zero forcing equalizer.

The fading signal is given by

$$\hat{h} = \sqrt{\frac{M}{\rho_\tau}} y_\tau \qquad (8)$$

The channel estimate $\hat{h}$ is used for estimating the transmitted signals with the equivalent channel model(5) and zero forcing detector.

i.e.,

$$\hat{s} = Quant[r_{zF}]$$

Where $r_{zF} = \frac{1}{\sqrt{\rho d}\left(H^H(\hat{h})H(\hat{h})\right)H^H(\hat{h})r}$

ZF-DFE Receiver:This detector consists of two steps. Here

$$H(\hat{h}) = (h_1, h_2, \ldots\ldots, h_K),$$

$$H_k(\hat{h}) = (h_1, h_2, \ldots\ldots, h_k)$$

$$g_k = \left(1/\sqrt{\rho d} \right) H_k(\hat{h}) \left(H_k^H(\hat{h}) H_k(\hat{h}) \right)$$

For $k = K, K-1, \ldots\ldots, 1$. Then basically the zero forcing-decision feedback equalizer is based on the training zero forcing detector and it can be described as follows:

The first step is estimate the fading channel is obtained by (8).

The second step is channel estimate $\hat{h}$ is regarded to be completely correct and used for detecting the transmitted signals with the equivalent channel model (5) and the coherent ZF-DFE detector.

This detection captures two procedures.

1) Initialization. The last symbols$s_K$of **s** is first detected using the ZF equalizer $g_K$with the channel matrix $H(\hat{h})$, i.e.,

$$z_K = y \qquad (9a)$$

$$\hat{s}_K = Quant[g_K^H z_K] \qquad (9b)$$

2) Recursion. Suppose that the previously already detected Symbols$\hat{s}_l$for $l = K, K-1, \ldots\ldots k+1$ are all correct, i.e.,$\hat{s}_l = s_l$. Then, the kth symbol of **s** is first detected using the ZF equalizer $g_k$with the channel matrix$H_k(\hat{h})$, i.e.,

$$z_k = z_{k+1} - h_{k+1}\hat{s}_{k+1} \qquad (9c)$$

$$\hat{s}_k = Quant[g_k^H z_k] \qquad (9d)$$

For $k = K-1, K-2, \ldots\ldots, 1$.

Full-Diversity Analysis

Here first analyze the average error performance of the ZF detector.

The received signal y_d can be represented by

$$y_d = \sqrt{\rho d} X_d(s)\hat{h} + \hat{w} \qquad (10)$$

where$\hat{w} = \sqrt{\rho d} X_d(s)(h - \hat{h}) + w_d$

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The covariance matrix is given by

$$\Sigma_{\hat{w}\hat{w}} = \sigma^2 \left({\rho_d}/{\rho_\tau} X_d(s) X_d^H(s) + I \right) \quad (11)$$

Equation (5) for the purpose detection can be equivalently rewritten as

$$r = \sqrt{\rho_d} H(\hat{h}) s + \hat{\varepsilon} \ (12)$$

After the ZF equalizer, the channel model (12) becomes

$$r_{ZF} = \frac{1}{\rho_d} \left(H^H(\hat{h}) H(\hat{h}) \right)^{-1} H^H(\hat{h}) r = s + \eta \quad (13)$$

where

$$\eta = \frac{1}{\sqrt{\rho_d}} \left(H^H(\hat{h}) H(\hat{h}) \right)^{-1} H^H(\hat{h}) \varepsilon$$

To analyze the error performance of ZF-DFE receiver, we notice that, under feedback, the received signal vector z_k in (9c) can be rewritten as

$$z_k = \sqrt{\rho_d} H_k(\hat{h}) s_{1:k} + \hat{\varepsilon} \quad (14)$$

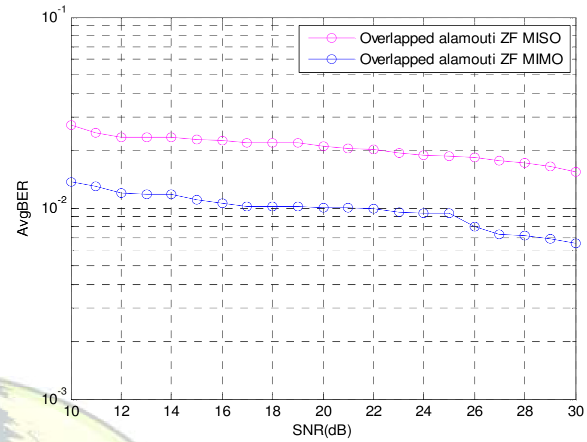
Where $s_{1:k} = (s_1, s_2, \dots \dots s_k)^T$

V. SIMULATIONS

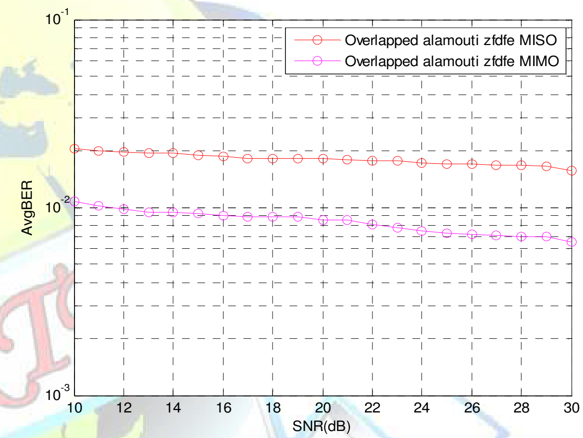
In this section, we analyze the error performance of STBC by carrying out comprehensive computer simulations. Here the number of transmitter and receiver antenna is 8.

STBC With Different Receivers

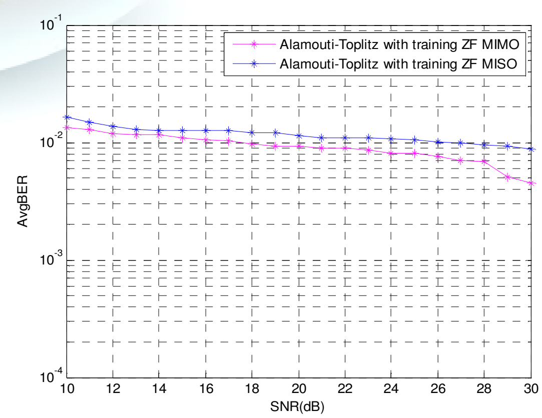
Here we examine the error performance of STBC based on overlap and Alamouti-Toeplitz codes with training ZF and ZF-DFE receiver. The symbol rate for the STBC is 9/16. We choose 16-QAM constellation, then the transmission bit rate is 9/4=2.25bits per channel use. And here the comparative results of MISO and MIMO based STBC are shown. Comparing the two system MIMO having less error then the MISO.



(a)



(b)



(c)

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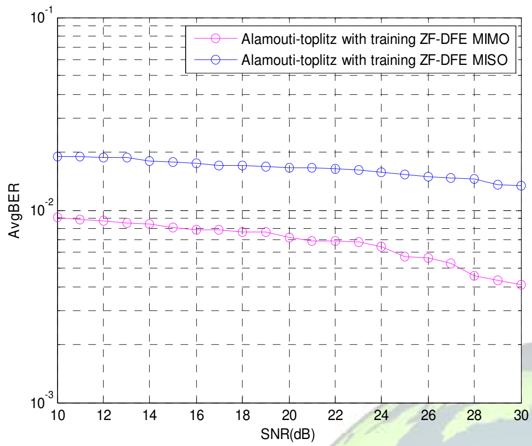

Figure. 2. Error performance comparison of STBC with ZF,ZF-DFE receivers.(a) Overlapped Alamouti with ZF MISO and MIMO.(b) Overlapped Alamouti with ZF-DFE MISO and MIMO. (c) Alamouti-Toeplitz with ZF MISO and MIMO.(d) Alamouti – Toeplitz with ZF-DFE MISO and MIMO.

I. CONCLUSION

In this paper, we proposed a criterion for STBC toachieve full diversity with ZF and ZF-DFE receiver in an MIMO system. And here we analyze the error performance of overlapped Alamouti STBC and Alamouti-Toeplitz STBC to achieve full diversity. And also the comparative results of Multi input single output and multi input multi output of different STBC are shown by computer simulations.

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